

**SYSTEM, METHOD, AND COMPUTER PROGRAM PRODUCT FOR
IDENTIFYING MANUFACTURING-SPECIFIC REGIONS IN OBJECT MODELS**

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TECHNICAL FIELD OF THE INVENTION

[0001] The present invention is directed, in general, to computer-aided design and modeling.

BACKGROUND OF THE INVENTION

10 [0002] Computer-aided design and modeling (CAD/CAM) have become an integral part of the process for designing and manufacturing any number of components. By designing, modeling, and revising the components in a data processing system, the product can be visualized and optimized as it
15 is being developed to ensure a correct design before any actual manufacturing takes place.

[0003] The ability to quickly find potential design problems which will impact manufacturing with high costs or other problems is a great advantage during this process.
20 To validate designed product models, it is necessary to define the character of each face and edge to determine the interrelation of each modeled part. There is currently no accurate, automated method for finding manufacturing related features such as parting lines, undercuts,
25 crossover faces, cavity and core regions.

[0004] There is, therefore, a need in the art for a system, process and computer program product for enabling a efficient and automated identification and characterization

of the above manufacturing related features in product models.

SUMMARY OF THE INVENTION

[0005] A preferred embodiment provides a system, method, and computer program product for decomposing a product model into manufacturing specific regions. Further, a preferred embodiment provides a corresponding system, method, and computer program product incorporating an object view visualization method for decomposing a product model into manufacturing specific regions.

[0006] The foregoing has outlined rather broadly the features and technical advantages of the present invention so that those skilled in the art may better understand the detailed description of the invention that follows. Additional features and advantages of the invention will be described hereinafter that form the subject of the claims of the invention. Those skilled in the art will appreciate that they may readily use the conception and the specific embodiment disclosed as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. Those skilled in the art will also realize that such equivalent constructions do not depart from the spirit and scope of the invention in its broadest form.

[0007] Before undertaking the DETAILED DESCRIPTION OF THE INVENTION below, it may be advantageous to set forth definitions of certain words or phrases used throughout this patent document: the terms "include" and "comprise," as well as derivatives thereof, mean inclusion without limitation; the term "or" is inclusive, meaning and/or; the phrases "associated with" and "associated therewith," as well as derivatives thereof, may mean to include, be

included within, interconnect with, contain, be contained within, connect to or with, couple to or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or with, have, have a property of, or the like; and the term "controller" means any device, system or part thereof that controls at least one operation, whether such a device is implemented in hardware, firmware, software or some combination of at least two of the same. It should be noted that the functionality associated with any particular controller may be centralized or distributed, whether locally or remotely. Definitions for certain words and phrases are provided throughout this patent document, and those of ordinary skill in the art will understand that such definitions apply in many, if not most, instances to prior as well as future uses of such defined words and phrases.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, wherein like numbers designate like objects, and in which:

[0009] Figure 1 depicts a block diagram of a data processing system in which a preferred embodiment can be implemented;

[0010] Figures 2A-2E illustrate an exemplary model as decomposed into cavity and core regions; and

[0011] Figure 3 shows a flowchart of a process in accordance with a preferred embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0012] FIGURES 1 through 3, discussed below, and the various embodiments used to describe the principles of the present invention in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the invention. Those skilled in the art will understand that the principles of the present invention may be implemented in any suitably arranged device. The numerous innovative teachings of the present application will be described with particular reference to the presently preferred embodiment.

[0013] A preferred embodiment provides a system, method, and computer program product for decomposing product a model into manufacturing specific regions. Further, a preferred embodiment provides a corresponding system, method, and computer program product incorporating an object view visualization method for decomposing a product model into manufacturing specific regions.

[0014] The disclosed method and system helps plastic and casting parts design engineers to easily find potential design problems that could affect manufacturing, and helps achieve product design optimization early as in the design stage. By using this system, mold/tooling design engineers can quickly find cavity/core regions and parting lines when designing cavities and cores, so productivity will be significantly improved.

[0015] **Figure 1** depicts a block diagram of a data processing system in which a preferred embodiment can be implemented. The data processing system depicted includes a

processor 102 connected to a level two cache/bridge 104, which is connected in turn to a local system bus 106. Local system bus 106 may be, for example, a peripheral component interconnect (PCI) architecture bus. Also connected to local system bus in the depicted example are a main memory 108 and a graphics adapter 110.

[0016] Other peripherals, such as local area network (LAN) / Wide Area Network / Wireless (e.g. WiFi) adapter 112, may also be connected to local system bus 106. Expansion bus interface 114 connects local system bus 106 to input/output (I/O) bus 116. I/O bus 116 is connected to keyboard/mouse adapter 118, disk controller 120, and I/O adapter 122.

[0017] Also connected to I/O bus 116 in the example shown is audio adapter 124, to which speakers (not shown) may be connected for playing sounds. Keyboard/mouse adapter 118 provides a connection for a pointing device (not shown), such as a mouse, trackball, trackpointer, etc.

[0018] Those of ordinary skill in the art will appreciate that the hardware depicted in **Figure 1** may vary for particular. For example, other peripheral devices, such as an optical disk drive and the like, also may be used in addition or in place of the hardware depicted. The depicted example is provided for the purpose of explanation only and is not meant to imply architectural limitations with respect to the present invention.

[0019] A data processing system in accordance with a preferred embodiment of the present invention includes an operating system employing a graphical user interface. The

operating system permits multiple display windows to be presented in the graphical user interface simultaneously, with each display window providing an interface to a different application or to a different instance of the same application. A cursor in the graphical user interface may be manipulated by a user through the pointing device. The position of the cursor may be changed and/or an event, such as clicking a mouse button, generated to actuate a desired response.

[0020] One of various commercial operating systems, such as a version of Microsoft Windows™, a product of Microsoft Corporation located in Redmond, Wash. may be employed if suitably modified. The operating system is modified or created in accordance with the present invention as described.

[0021] A disclosed method includes decomposing a product model into manufacturing-specific sub-regions, according to typical manufacturing operations requirements.

[0022] The sub regions are described in Table 1:

Region Category	Manufacturing property
Cavity faces	Formed in cavity side
Core faces	Formed in core side
Parting lines	Outer boundary of cavity and core regions
Patch loops	Inner boundary of cavity and core regions
Crossover region faces	Need be split and formed in both sides
Crossover vertical faces	Need draft added or formed in one side
Undercut faces	Need slide or lifter system operation
Undercut edges	Will bring undercut faces

[0023] As shown in Table 1 and understood by skilled artisans, cavity and core faces are used for cavity and core design of mold/tool respectively, and must be identified and extracted out as cavity and core regions for mold/tool design.

[0024] Parting lines are the boundary (with maximum length) of cavity and core regions, from which parting surfaces will be created. Patch loops are the boundaries of cavity and core regions other than parting lines, and are used to create patch surfaces for mold/tool design.

[0025] Crossover region faces are the faces which partly stay in cavity side and partly stay in core side, so they need to be split in middle (along isocline) to avoid undercuts for mold/tool release. Crossover vertical faces are the faces without draft, they need to be added draft or assigned either in cavity or core side.

[0026] Undercut faces needs special mechanism systems (lifter or slider) in mold/tool design, which incur a correspondingly with high cost. Unnecessary undercuts need

to be removed in product design to achieve design optimization. Undercut edges are used to help identify undercut faces.

[0027] An object view visualization method is used to decompose a product model into manufacturing-specific regions. The method is described as below:

[0028] First, based on draw (mold release) direction, the top and bottom views for the product model are generated. Visible and invisible faces and edges of the product model in each view are determined and assigned an object name as shown in Table 2:

Object Name	Visibility in view
F1	Top view visible face
F2	Bottom view visible face
E1	Top view visible edge
E2	Bottom view visible edge

[0029] Next, a set of rules is used to automatically assign the above-listed manufacturing specific regions from the product model. These rules are shown in Table 3 below:

Category	Rule
Cavity face	F1 only
Core face	F2 only
Crossover face	F1 and F2
Undercut face	Non F1 and Non F2
Undercut EDGE	Non E1 and Non E2
Parting EDGE	Its adjacent faces belong to cavity and core face respectively
Parting line loop	Maximum loop length against draw direction.
Patch loop	Loop other than the parting line loop.

[0030] Figures 2A-2E illustrate an exemplary model as decomposed into cavity and core regions. Figure 2A shows the product model in top view. Figure 2B shows the product model in bottom view. Figure 2C shows the cavity region of the product model. Figure 2D show the core region of the model. Figure 2E shows the parting lines and patch loops of the product model.

[0031] The disclosed system and method provides a much more accurate solution in finding parting lines, undercuts, crossover faces than many of the existing solutions. In current solutions addressing the above issue, classification of faces in the product model is through the use of face draft analysis. Based on the results of face draft analysis, faces are first put into the positive and negative groups. Next, the positive faces are assumed to be the cavity faces, and negative faces for the core faces. This assumption may not be always correct because a positive face may be a core face and a negative face may be a cavity face. Therefore, those solutions will often generate incorrect results in finding parting lines and undercuts.

[0032] The disclosed system and method can automatically recognize cavity and core regions, a capability unavailable in the current product market.

[0033] Figure 3 shows a flowchart of a process in accordance with a preferred embodiment. Here, the system will first select a product solid model, either automatically or by receiving a user selection (step 305). A draw direction (mold release direction) will then be

specified, either by the user or according to the model design file (**step 310**).

5 **[0034]** The system will then generate top view (**step 315**) and identify all faces and edges of model which are visible in top view (**step 320**). The outputs will be as shown in Table 2: F1, Non F1, E1 and Non E1.

10 **[0035]** The system will then generate bottom view (**step 325**) and identify all faces and edges of model which are visible in bottom view (**step 330**). As above, the outputs will be as shown in Table 2: F2, Non-F2, E2 and Non-E2.

[0036] The system will then assign manufacturing-specific regions to each face and edge based on the rules shown in Table 3, above (**step 335**).

15 **[0037]** The rules are preferably applied in the following sequence:

[0038] 1) If a face is <F1 only>, then it is assigned to the Cavity Face region.

[0039] 2) If a face is <F2 only>, then it is assigned to the Core Face region.

20 **[0040]** 3) If a face is < F1 and F2>, then it is assigned to the Crossover Face region.

[0041] 4) If a face is < Non-F1 and Non-F2>, then it is assigned to the Undercut Face region

25 **[0042]** 5) If an edge is < Non-E1 and Non-E2>, then it is assigned to the Undercut Edge region.

[0043] 6) If an edge has its two adjacent faces belonging to a cavity and a core face each, then it is assigned to the Parting Edge region.

5 [0044] 7) Parting loops are comprised of parting edges, among all parting loops. A Parting Line Loop is defined as the one with maximum loop length against draw direction.

10 [0045] 8) After the parting line loop is identified, the other loops are Patch Loops (internal holes).

[0046] Finally, the system will store the assigned manufacturing-specific regions (**step 340**).

15 [0047] Those skilled in the art will recognize that, for simplicity and clarity, the full structure and operation of all data processing systems suitable for use with the present invention is not being depicted or described herein. Instead, only so much of a data processing system as is unique to the present invention or necessary for an
20 understanding of the present invention is depicted and described. The remainder of the construction and operation of data processing system 100 may conform to any of the various current implementations and practices known in the art.

25 [0048] It is important to note that while the present invention has been described in the context of a fully functional system, those skilled in the art will appreciate that at least portions of the mechanism of the present

invention are capable of being distributed in the form of a instructions contained within a machine usable medium in any of a variety of forms, and that the present invention applies equally regardless of the particular type of instruction or signal bearing medium utilized to actually carry out the distribution. Examples of machine usable mediums include: nonvolatile, hard-coded type mediums such as read only memories (ROMs) or erasable, electrically programmable read only memories (EEPROMs), user-recordable type mediums such as floppy disks, hard disk drives and compact disk read only memories (CD-ROMs) or digital versatile disks (DVDs), and transmission type mediums such as digital and analog communication links.

[0049] Although an exemplary embodiment of the present invention has been described in detail, those skilled in the art will understand that various changes, substitutions, variations, and improvements of the invention disclosed herein may be made without departing from the spirit and scope of the invention in its broadest form.

[0050] None of the description in the present application should be read as implying that any particular element, step, or function is an essential element which must be included in the claim scope: THE SCOPE OF PATENTED SUBJECT MATTER IS DEFINED ONLY BY THE ALLOWED CLAIMS. Moreover, none of these claims are intended to invoke paragraph six of 35 USC §112 unless the exact words "means for" are followed by a participle.